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Energy recovery potential from excavating municipal solid waste dumpsite in Indonesia

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Abstract

There is no proper intermediate treatment for municipal solid waste in Indonesia before dumped in a landfill. Most of the Indonesian dumpsite already over capacity and need intensive treatment. This study examines Jatibarang Dumpsite in Semarang City, Indonesia to assess the material recovery potential for solid fuel. After excavation obtained material consist of 46% of the combustible material (organic and plastic), 52% of the fine particle, and 2% of the incombustible material (metal and glass). A simulation of incineration with the steam turbine is used to predict the electricity generation. The simulation results show that the amount of electricity produced could reach 461.67 kW with CO_2 emission up to 0.18 kg/sec.

Keywords: landfill mining; Aspen Plus; municipal solid waste

1. Introduction

Indonesia has the world fifth largest population in the world with a total of 26.1 million people during the census in 2016. Indonesia economic also growing stronger 5.2% in the fourth quarter in 2017. Despite rapid population and economic growth, the infrastructure development especially waste management is very slow. About 69% of waste

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was landfilled, and 10% of waste was dumped with no treatment [1]. Although the Law. 18/ 2018 required all landfill and dumpsite to be transformed into a sanitary landfill; only a few municipalities obey the rules [2]. This condition has led to the huge environment and social problem.

With the enactment of Presidential Decree No. 35/2018, Indonesia has started a new chapter in the development of waste management technology. The decree entitled "Development Acceleration of Waste to Electricity Facility Based on Eco-Friendly Technology" mentioned that 12 biggest cities in Indonesia should build a waste to electricity plant to tackle the problem caused by domestic waste. The national electric company is obliged to buy the electricity produced with the price up to 14.54 cent/kWh[3]. Although the government has huge ambition on this project, current waste management system is not compatible to sustain constant feedstock for that kind of technology. Most of the Indonesian waste is going to the dumpsite without any proper intermediate treatment. A huge amount of waste has been accumulated from years ago and potentially become constant feedstock for Waste to Electricity Plant [4]. By excavating the landfill and recover the land, not only we could solve the waste problem but also reduce the pollutant in the air, water, and soil [5].

Current waste to energy plant does not only act as waste treatment but also aim to increase resource conservation and recovery [6–8]. Using pretreatment process such as hydrothermal treatment could increase the quality of the feedstock [9,10]. Combination of thermal treatment with the steam engine is one way to produce electricity from waste. Thailand and Belgium excavated waste produced similar output in waste to energy plant although they have different waste composition [11]. Gasification on char produced from excavated waste could increase its activation energy up to 83 kJ/mol [12]. There is still lack of studies about the excavated waste potential in tropical countries. This work tries to fill the gap of the work in this field by examining Jatibarang Dumpsite in Indonesia. Detail excavation process and fuel analysis were done thoroughly. Simulation using Aspen Plus was done to predict the possible electricity generation in various condition.

2. Excavation Process

Jatibarang Dumpsite site is located at Mijen District, south-west area of Semarang City, Central Java Province, Indonesia. The site is managed by Environmental Agency of Semarang City and has been receiving waste from Semarang City since 1992. The amount of waste dumped in Jatibarang Dumpsite was up to 974 tons/day in 2016 and was predicted to reach 1600 tons/day in 2020. The dumpsite covers an area up to 46 ha equipped with leachate ponds, compost and RDF factory, office and garage. Aerial photo and Site Map of Jatibarang Dumpsite is shown in Figure 1. The operating area was divided into three zones. Active Zone 1 accepts most of the waste coming to the landfill. Active Zone 2 was used as a backup area when the number of waste suddenly increase in a day. The Passive Zone is currently an inactive area. Previously used as a dumpsite, after it reaches its maximum capacity, the management close the area and plant greenery on the surface. We can see cattle grazing on the passive zone during the day.

Fig. 1 Aerial photo and site map of Jatibarang Landfill

The excavation was done using standard backhoe with scoop volume around 0.8m3. The backhoe made hole up to 3 meters at three random points in every zone. For every meter, scoops of waste were taken for further analysis. The composition of excavated waste in each zone could be seen in Figure 2.

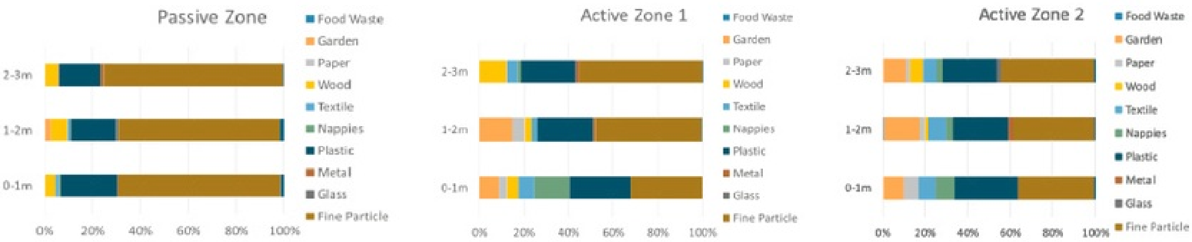

Fig. 2 Composition of excavated waste in passive zone, active zone 1 and active zone 2

As seen in Figure 2, there is huge potential for refused derived fuel harvesting since the combination of organics and plastics could make up more than half of the composition in each layer.

Thermal oxidation such as incineration is a common method to generate heat from waste material. The heat then transferred to the boiler for a steam engine. During incineration, hydrocarbon in waste will be converted to H_2O, CO_2, and another pollutant through the combustion process. It is necessary to understand the constituent element of the material before designing efficient combustion process. The ultimate analysis will determine the percentage of carbon, hydrogen, oxygen, nitrogen, sulfur, and ash in the material. In this study, we use Vario MICRO Cube elemental analyzer (Elementar, Germany) for ultimate analysis. The analysis was conducted in dry ash free (daf) basis after removing the moisture. The result of elemental analysis of plastic and organic part in composition percentage is presented in Figure 3 and Figure 4.

The ultimate analysis shows that the degradation process in the dumpsite is heterogeneous. Different places have the different waste characteristic. From the analysis, we can get the general overview of all elemental constituent of the excavated waste. The summary of ultimate analysis is presented in Table 1.

Fig. 3 Ultimate analysis of excavated plastic waste

Fig. 4 Ultimate analysis of excavated organic waste

Table 1 Summary of ultimate analysis of excavated plastic and organic material in % daf

	Plastic								
	H	C	N	S	O(by diff)	Ash	F	Cl	Br
Mean	7.03	44.81	0.79	0.47	13.74	31.94	0.08	1.13	0.01
Maximum	13.05	73.55	1.2	0.98	25.79	60.3	0.36	4.16	0.04
Median	6.69	40.7	0.87	0.19	13.91	36.1	0.02	0.29	0
Minimum	2.51	15.32	0.28	0.1	2.19	10.6	0.01	0.1	0
	Organic								
Mean	3.59	28.77	1.42	0.69	26.00	38.94	0.05	0.46	0.07
Maximum	5.27	40.14	2.12	0.98	39.06	61.8	0.16	0.86	0.45
Median	3.26	27.3	1.33	0.8	23.27	43.1	0.03	0.43	0.03
Minimum	2.08	17.05	0.98	0.1	15.3	15.9	0.01	0	0

The analysis for calorific value was done using Bomb Calorimeter and measured by Solid Waste Laboratory of Diponegoro University, Indonesia. The measurement was done using composite waste consist of a proper composition of combustible waste according to Figure 1. High Heating Value (HHV) of combustible excavated waste is presented in Table 2 below.

Table 2 Calorific value of combustible excavated waste

Zone	Depth (m)	HHV (MJ/kg)
Active Zone 1	0-1	25.42
	1-2	23.27
	2-3	23.25
Active Zone 2	0-1	23.84
	1-2	25.43
	2-3	24.91
Passive Zone	0-1	21.98
	1-2	24.12
	2-3	26.45

3. Utilization of Combustible Excavated Waste for *Waste-to-Energy* Electricity Generation

The possibility of excavated waste to be used as feedstock will be assessed using Aspen Plus V8.8 (Aspen Technology, Inc.) process simulator software package. We build a model and performed calculations associated with material and energy balances. The chemical properties explained previously will be used as a baseline parameter. Weather condition uncertainty in Indonesia has become a challenge to control the moisture content. Thus, sensitivity analysis with moisture variation will be performed. Schematic process flow diagram of the power generation system is shown in figure 5.

We use combustible excavated waste for the feedstock. It consists of organic waste (44%) and plastic waste (56%) Using basic input, the total electricity produced is 461.67 kW with CO_2 emission up to 0.18 kg/sec. The Sensitivity Analysis was done by a variation on moisture content in the feedstock. The moisture content of organic waste was set from 10% to 50%, while the moisture content of plastic waste was set from 0.01% to 30%. Figure 6 shows the results

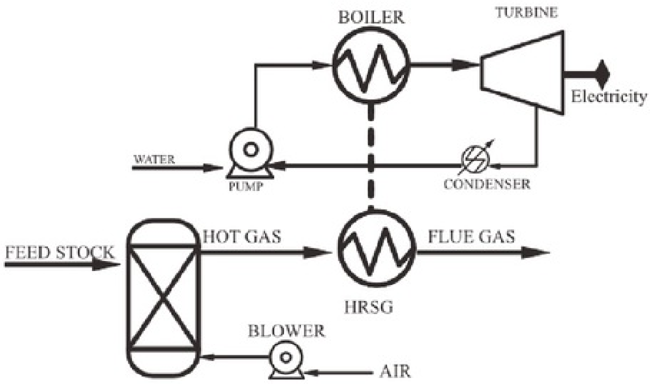

Fig. 5 Process Flow Diagram of Waste Incineration Coupled with Steam Engine

of the effect on moisture content variation towards electricity generation.

Lower plastic to organic ratio lead to higher electricity generation. The highest electricity produced is 485.25kW. It was on the condition when the plastic moisture content is 0.01%, and organic moisture content is 10%. On the other hand, the lowest electricity produced is 352.92kW. It was on the condition when the plastic moisture content is 30.01%, and organic moisture content is 50%. Since the plastic waste tends to have a low moisture content, its characteristic has become the main driving force to determine the amount of electricity produced.

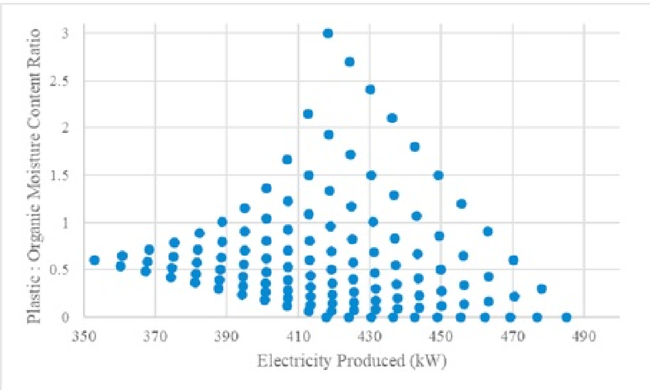

Fig. 6 Effect of Plastic/Organic Moisture Content Ration to Electricity Production

4. Conclusion

This study focus on finding the potential of excavated municipal solid waste for energy recovery. The dumpsite in Semarang City, Indonesia was chosen as a case study for this research. In general, the excavated waste is consist of 46% of the combustible material (organic and plastic), 52% of fine particle and 2% of the incombustible material (metal and glass). The combustible material itself is consist of 44% organic and 56% plastic. Make it huge potential feedstock for waste to energy power plant. Aspen Plus simulation was done to predict the possible electricity production based on chemical and phase equilibrium of combustible material during incineration. The basic scenario could generate 461.67 kW of electricity. Moisture content is the key parameter to increase the efficiency process. Additional pretreatment to reduce the moisture content is necessary. The sensitivity analysis shows that if the moisture content could be reduced up to 0.01% for plastic and 10% for organic, we could generate electricity up to 485.25 kW.

The problem of municipal solid waste in Indonesia force the government to accelerate the development of waste to energy technology. In this April, the ratify new Presidential Decree to stimulate this technology. Waste to energy is costly and if not well managed could lead to environmental disaster. The future research to assess the economic and environmental feasibility is needed for this technology to be implemented.

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